TELEPHONE TRAFFIC - DIAL CENTRAL OFFICE EQUIPMENT SWITCH QUANTITIES

Purpose: The purpose of this addendum is to describe in detail the calculation of the number of trunks required when an interoffice group is divided into one-way and two-way subgroups as described in Paragraphs 4.2, 4.4, and 4.55. Directional splitting is economical on EAS groups of 11 or more trunks and it often is advantageous on toll connecting groups. The traffic on a toll group between a tributary and its toll center may be unequal in the two directions during some hours because of the effect of time zones and reduced rate periods. Also, when DDD service is provided over a one-way group to the ticketing center, the remaining toll trunks will carry more inward than outward traffic. These factors must be taken into account in any directional division of a toll group in order to avoid an adverse effect on service.

Additions: 4.41 Paragraph 4.4 of this section states that " - - - it will be satisfactory to assume that combination trunk groups are as efficient as a regular graded group." For most REA systems this has been sufficiently accurate. However, there is some loss in efficiency when trunk groups are divided directionally, even where there are some two-way trunks in the group. The load that can be carried on divided groups is shown in attached Table 1.

4.42 The trunk group capacities in Table 1 were derived from the following equation:

$$\text{Capacity total group } (2A + B) = \text{Capacity } (A + B) \frac{2A + B}{A + B}$$

Where:

A = number of one-way trunks in each direction (traffic assumed equal in two directions).

B = number of two-way trunks.

For example, with a group of 16 trunks divided into 4 in each direction and 8 in both directions $A = 4 \quad B = 8$

Capacity of a group of (A + B) or 12 trunks (P = .03) = 230 unit calls (REA TE & CM-510 - Figure 2A)

$$\text{Capacity of } (2A + B) \text{ or } 16 \text{ trunks} = 230 \frac{8 + 8}{4 + 8} = 307 \text{ u.c.}$$

A group of 16 two-way trunks with regular grading has a capacity of 318 u.c. at P = .03 grade of service. (Figure 2A). The loss of efficiency, therefore, by splitting the group as indicated is 318-307 = (11 ÷ 318) x 100 or 3.3 percent.

By the use of the above equation, the capacity of a divided trunk group can be calculated for any combination of one-way and two-way trunks.

In practice, it is considered advisable to provide a minimum of 5 two-way trunks for groups of up to 25 trunks to care for normal fluctuations in the flow of traffic in the two directions.

4.43 Attached Table 1 and Figure 1 show the recommended division of trunks and the grading for divided groups of 11 to 25 trunks at both terminals of a trunk group. The grading was developed on the basis of using all 10 terminals of the selector banks. Other combinations, of course, are possible and the capacity of any trunk split can be calculated as described.

4.44 If there is reason to believe that the traffic on a group is not equal in the two directions, a different number of one-way trunks in t two directions may be provided. This will be the case in a toll group handling outward CLR plus inward traffic when a separate group is used for access to DDD. In practice, it is not customary to divide such groups except perhaps for those with 11 or 12 trunks where the last one or two trunks might require an extra shelf in a step-by-step office.

4.45 On any divided group it is suggested that the trunk overflow registrations at the two terminals be compared at regular intervals and, if there is a material difference, adjustments be made in the number of one-way trunks assigned to each office.

TRUNK CAPACITY TABLE FOR DIVIDED GROUPS
TEN-TERMINAL ACCESS

Number of Trunks				Capacity-Unit Calls Grade of Service		
Total	In	Out	Two-Way	P = .01	P = .03	P =
11	1	1	9	164	196	2
12	2	2	8	179	214	2
13	3	3	7	194	232	2
14	4	4	6	209	249	2
15	5	5	5	224	267	2
16	4	4	8	259	307	3
17	4	4*	8#	273	323	3
18	5	5	8#	286	338	3
19	6	6	7	313	368	3
20	6	6*	7#	327	384	4
21	7	7	7#	340	399	4
22	8	8	6	366	430	4
23	8	8*	6#	380	446	4
24	9	9	6#	394	462	4
25	10	10	5	420	493	5

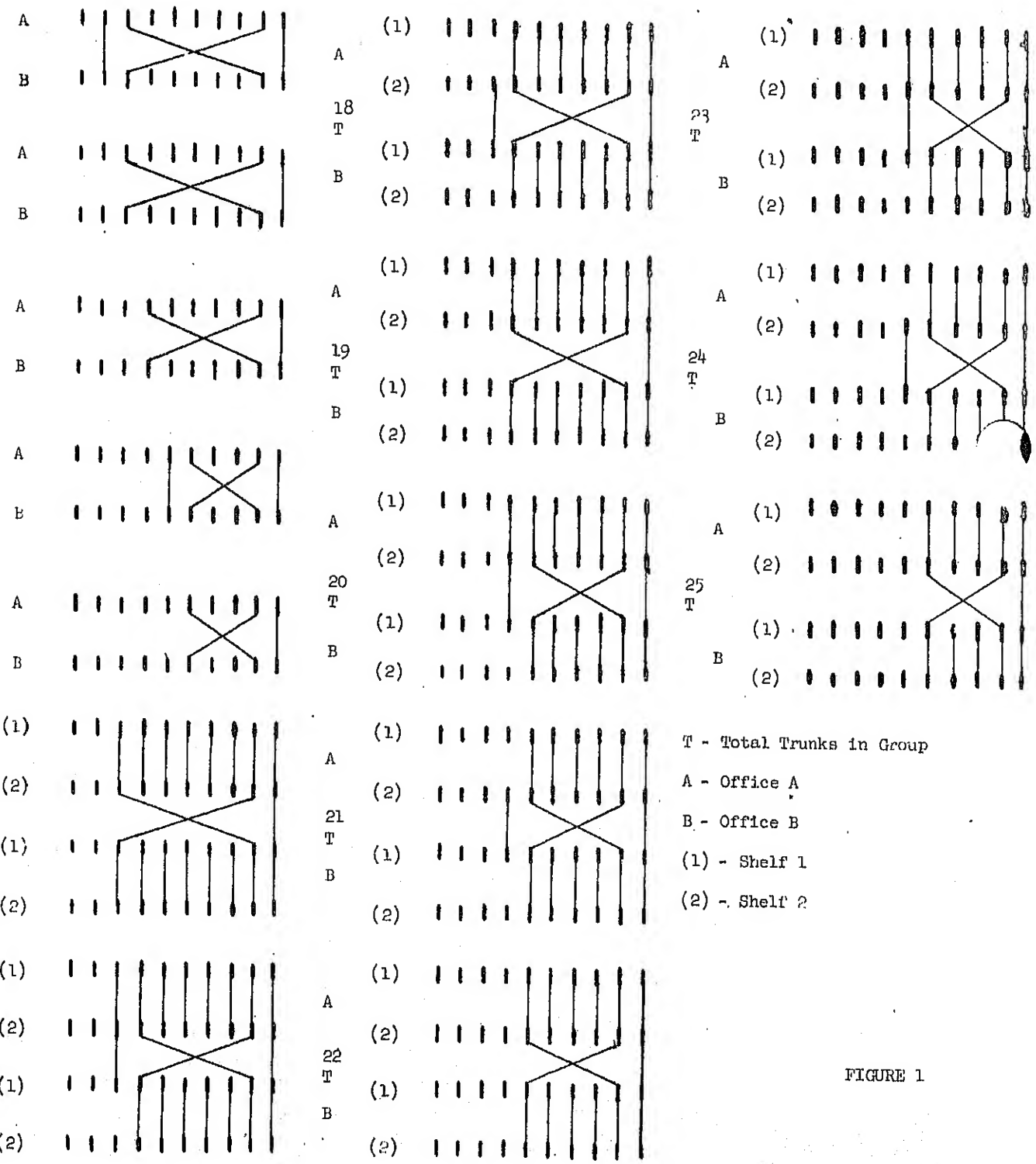
* One more in one direction. See Figure 1

\# One not terminated on one shelf. See Figure 1

TABLE 1

GRADED MULTIPLE ARRANGEMENTS

TRUNK GROUPS DIVIDED DIRECTIONALLY



T - Total Trunks in Group

A - Office A

B - Office B

(1) - Shelf 1

(2) - Shelf 2

FIGURE 1

TELEPHONE TRAFFIC - DIAL CENTRAL OFFICE EQUIPMENT SWITCH QUANTITIES

Purpose: This addendum replaces Addendum No. 1 dated August 1961. It changes the recommended basis of engineering toll connecting trunks from a probability of three or five delays in a hundre calls (P = .03 or P = .05) to one to three delays in a hundre calls (P = .01 - P = .03). It also changes the recommended basis of engineering nontoll connecting trunks from a proba- bility of five or ten delays in a hundred calls (P = .05 or P = .10) to three to five delays in a hundred calls (P = .03 P = .05). This more liberal provision of interoffice trunks is in accordance with standards being adopted by the telephon industry. Due to the adverse effect of delays on service, it is now recommended that these groups be engineered more liberally than in the past.

Changes: Following are the revised paragraphs of REA TE & CM-510 incor porating this change in the provision of toll connecting trun

3.23 The grade of service for interoffice trunks, in general will vary from P = .01 to P = .10, depending on economi factors and the class or classes of traffic to be route over the group. It is an observed fact that for all types of interoffice trunks the subscriber considers th the grade of service rendered should be excellent if th distance to the called office is small; on the other hand, a somewhat poorer grade of service will be tolera when the called office is some distance away. The sub- scriber will become impatient more quickly with inabili to get an operator, particularly on an emergency call, than with inability to get another subscriber. These a other considerations enter into determining an appropri grade of service for interoffice trunks. The grades of service for nontoll connecting (formerly EAS and short haul toll) trunks, in general, will vary from P = .03 t P = .10, depending on the cost, classes of traffic to b routed over the group and on the type of community serv by the trunk group.

3.24 For average conditions it is suggested that the following table be used to determine the number of trunks to provide:

Toll Connecting	Nontoll Connecting
P = .01 - .03	P = .03 - .05

(1) EXCEPTIONS: Some less liberal provision of trunks may be justified for unusual situations where the community served by the trunk group is such that the peak traffic each year is of short duration. A resort or truck farming area where the marketing season is short would be examples. Also, less liberal provision of trunks would be justified where the cost of trunk facilities is excessive. Under unusual conditions a grade of service as low as .05 may be justified for toll connecting trunks and .10 for nontoll connecting trunks. The P = .03 grade of service for nontoll connecting trunks would be desirable: (1) for large trunk groups; (2) for trunk groups used in tandem; (3) for short haul toll; (4) where the distance between offices is very short (a mile or so); (5) for any cases where no significant economic penalties are incurred.

(2) Where one or more "high usage" toll connecting groups are provided between a tributary and offices other than its regular toll center, they would, of course, be engineered on a basis of delay much greater than P = .01.

4.554 The grades of service in accordance with paragraph 3.24 are:

Group	EAS	Toll	Grade of Service
A - B	X		.05
A - D		X	.01
B - C	X		.05
B - D		X	.01
C - D		X	.01

4.555 Consider group A - B. The number of unit calls to be carried is 5.7 at P = .05. From Figure 2A for this grade of service:

No. of Trunks	No. of Unit Calls	Unit Calls Difference
1	1.9	11.0
2	12.9	

From paragraph 3.22:

10 percent x 11.0 = 1.10

If one trunk is to be provided, the maximum traffic which the group may carry is:

1.9 + 1.1 = 3.0

Since the number of unit calls to be provided for exceeds 3.0, the next higher trunk group is provided and, N = 2.

ANS. The grade of service is between .01 and .02.

4.556 In a similar manner, the number of trunks for each of the other groups is determined:

Group	Objective (P)	Unit Calls (Busy Hour)	No. of Trunks	Quality of Service Better Than (P)
A - D	.01	10.4	3	.01
B - C	.05	27.8	3	.05
C - D	.01	67.4	7	.01
B - D	.01	216	13	.02

TELEPHONE TRAFFIC - DIAL CENTRAL OFFICE EQUIPMENT SWITCH QUANTITIES

CONTENTS

1. GENERAL

1.1 This section is intended to provide REA borrowers, consulting engineers, contractors and other interested parties with technical information for use in the design and construction of REA-financed telephone systems. It discusses in particular considerations in the calculation of switch quantities for dial central offices and replaces Section 510, Issue 3, August 1954.

1.2 The purpose of this section is to provide means of determining the proper types, quantities and grouping arrangements of equipment that should be furnished in a dial central office on the basis of traffic considerations. It is intended that this material also serve as a guide to the borrower's engineer in verifying that the equipment schedule furnishes the correct number of switches or switching circuits in accordance with

Reprinted 1/64
With Addendum No.2 1/62

originating traffic estimates and the number of inter-office trunks stated in the central office equipment contract. In any case, however, the provisions of the central office contract govern any situation on an individual project.

1.3 Although the functions of these equipments are discussed briefly in this section, it is assumed that the reader has familiarized himself with Section 325 of this manual; REA Form 525 (hereinafter called the C. O. Specifications), and other sections in the 500 series of this manual. In this section an attempt has been made to keep the examples as simple as possible so that the basic principles of traffic engineering for small dial offices will be understood. Detailed arrangements required in these offices for operation on a 2-letter 5-digit numbering basis have been omitted, as this subject is covered in Section 208.

1.4 Switching equipments which generally apply only to offices of capacity greater than 800 lines are beyond the scope of this section and should be given special study by the engineer.

1.5 In the examples which follow, line terminals and connector terminals required for test and alarm purposes as well as those to be provided as spare are not specifically covered in each example. The number of these required must be added to the number required for subscriber lines to determine the total line and terminal requirements for an office being engineered.

1.6 Certain refinements are also omitted in the illustrative examples. For instance, there is normally some holding of linefinders by customers and permanents without digits being dialed. These attempts are generally referred to as "false starts". However, in this section it is assumed that all traffic on linefinders will be routed over trunks from the first selectors.

2. SWITCHING STAGES

2.1 The intra-office subscriber line to subscriber line switching arrangements employed in dial central offices which find application in most REA-financed systems are of three basic types:

Number of Stages	Switching Equipment Required	Ultimate No. of Lines
1	Linefinder-Connector (Links)	100 or 200 ("Broadspan")
2	Linefinder-Selector-Connector	*800
3	Linefinder-1st Selector-2nd Selector-Connector	*Over 800

*Extended area service or terminal per station operation may cause the introduction of second selectors with less than 800 lines.

2.2 Each of the selector systems above may require the use of second and sometimes third selectors for infrequent conditions where trunks must be provided for such services as wire chief, information, business office and revertive calls.

3. GRADES OF SERVICE

3.1 Intra-office trunks.

3.11 The central office dial switching equipment should be provided on a basis which will result in approximately three calls in each 100 encountering an all trunk busy condition during the busy hour of the last busy season before an addition to the office is expected. This three percent lost calls applies to the switching equipment used after dial tone is received. A call attempted when all linefinders are busy is delayed and can be completed if the calling party continues to hold his line until a linefinder becomes available. Copies of "Intra-office Trunk Capacity Tables", found in the C. O. Specifications, are included in this section as Figures 1A and 1B. As of this date only the Leich Company uses Figure 1B for determining switch quantities.

3.12 The C. O. Specification requires that if the traffic to be carried by an intra-office trunk group exceeds the traffic carrying capacity of a given number of trunks as indicated in Figures 1A and 1B by one unit call or more, the next higher number of intra-office trunks should be provided.

3.2 Inter-office trunks.

3.21 Inter-office trunks will usually be engineered on the assumption that the dial switching equipment will have access to only ten trunks on a level. Figure 2A should therefore be used. When it is known that the C. O. equipment will have fifteen terminal per level access, Figure 2B should be used to determine inter-office trunk quantities. In addition to determining the number of inter-office trunks, Figure 2A or 2B should also be used to determine the number of revertive call switches. Figure 3 is furnished principally to show grades of service outside the range of Figures 2A or 2B. Note that it assumes all of the trunks in the trunk group are available (full access) so that for large groups of trunks it is not useable.

3.22 In this section the convention is followed that, if the traffic to be carried by an inter-office trunk group exceeds the traffic-carrying capacity of a given number of trunks (as indicated in Figure 2A or 2B) by more than 10 percent of the difference between the number of unit calls corresponding to that number of trunks and the number of unit calls corresponding to the next higher trunk group, the next higher number of trunks should be provided. This will be illustrated in examples which follow.

3.23 The grade of service for inter-office trunks will in general vary from P = .03 to P = .10, depending on economic factors and the class or classes of traffic to be routed over the group. It is an observed fact that for all types of inter-office trunks the subscriber unwittingly considers that the grade of service rendered should be excellent if the distance to the called office is small; on the other hand, a somewhat poorer grade of service will be tolerated when the called office is some distance away. The subscriber will become impatient more quickly with inability to get an operator, particularly on an emergency call, than with inability to get another subscriber. These and other considerations enter into determining an appropriate grade of service for inter-office trunks.

3.24 The grades of service for toll connecting (formerly toll tributary) trunks will in general vary from P = .03 to P = .05, and those for non-toll connecting (formerly EAS and short haul toll) from .05 to .10, depending on the length and type of trunks, classes of traffic to be routed over the group and on the type of community served by the trunk group. For average conditions it is suggested that the following table be used to determine the number of trunks to provide:

	Toll Connecting 1, 2, 3	Non-Toll Connecting 1, 3
Groups up to 8 miles in length	P = .03	.05
Groups over 8 miles in length	P = .05	.10

(1) EXCEPTIONS: Some less liberal provision of trunks may be justified for unusual situations where the community served by the group is such that the peak traffic each year is of short duration. A resort or a truck farming area where the marketing season is short would be examples. Also, less liberal provision of trunks would be justified where the cost of trunk facilities is excessive. Under extreme conditions a grade of service as low as 0.10 may be justified for toll connecting trunks. On the other hand, more generous provision of trunks would be desirable (1) for large trunk groups (note that Figures 2A and 2B make no provision for grades of service poorer than .05 for groups of over 10 trunks), (2) where the distance between two larger offices is very short (a mile or so), (3) or for any cases where no significant economic penalties are suffered.

(2) Only toll connecting (see paragraph 4 for definition) trunks are included in this category.

(3) A single inter-office trunk group which carries a combination of toll destined for the nationwide toll system and extended area service traffic should be engineered to the same grade of service as if all calling were toll. On the other hand, a toll trunk group which carries only terminating traffic, that traffic which is never carried by the nationwide toll switching system, should be engineered on the same basis as non-toll connecting trunk group.

4. INTER-OFFICE TRUNKS

4.1 Inter-office traffic is herein considered as divided into two broad classifications: toll connecting and non-toll connecting. A toll connecting trunk is one which provides a means of connecting the local exchange to the nationwide toll system at a toll center; such a group usually includes operator office traffic. A non-toll connecting trunk group carries toll traffic which is never included in the nationwide toll switching plan or nothing but non-toll (EAS) calls. Groups carrying a combination of these types of traffic are possible.

4.2 Inter-office trunks may be arranged for traffic in one direction only, or in two directions, the former being called one-way trunks and the latter two-way. Incoming one-way trunks require an incoming selector or connector at one end only; whereas all two-way dial trunks require an incoming selector or connector at each end.

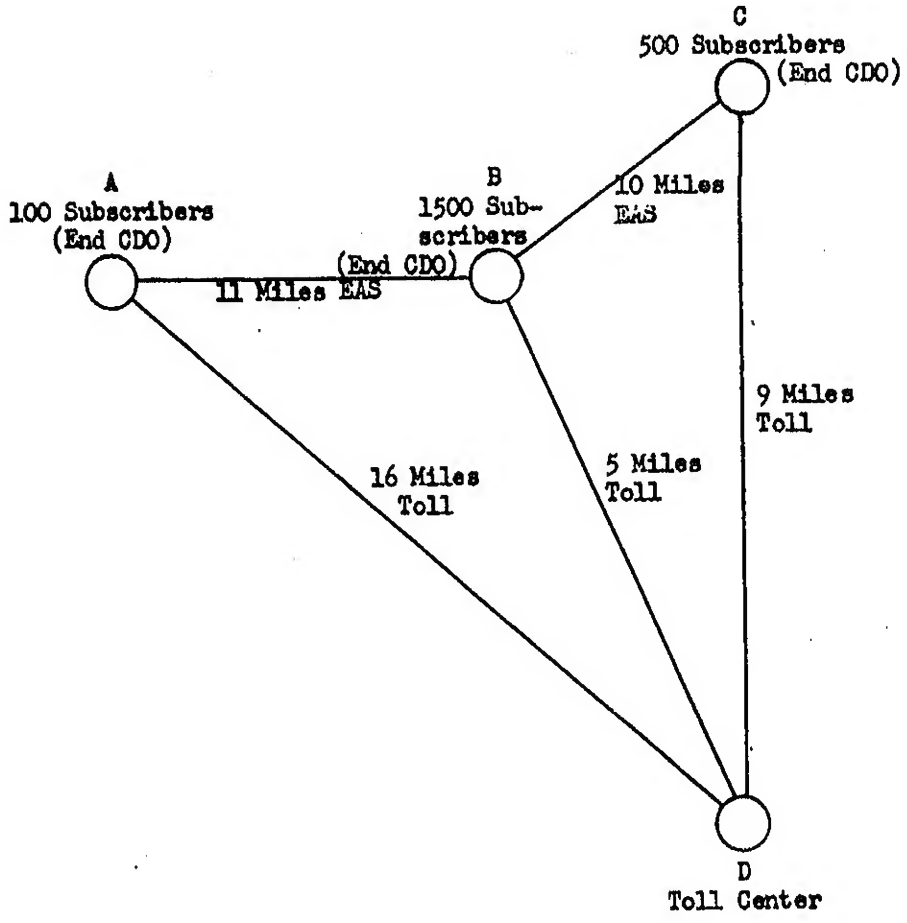
4.3 If there is to be traffic in both directions, it is necessary that one-way trunks be in two groups, one for each direction. One group of two-way trunks may be used for operation in both directions. It is always true that where there is calling in both directions between two points, the trunk group efficiency of two-way trunks is greater than that of one-way trunks. Therefore, more one-way trunks are necessary for a given amount of traffic and grade of service than two-way trunks.

4.4 The choice between one-way and two-way trunks resolves itself into balancing the saving in central office equipment against the increased cost of outside plant or carrier channels to provide for the greater number of paths for one-way trunking. Two-way trunks should be provided if from 1 to 10 trunks are required initially. If from 11 to 30 trunks are required initially, it will generally be economical to provide some one-way and some two-way trunks. This plan of providing some individual one-way trunks from each office with a group of two-way trunks as last choice at <u>both</u> offices will compensate for errors in the estimate of the traffic in each direction. Trunking in this manner becomes a form of graded multiple with one or more legs of the grade in each office so it will be satisfactory to assume that combination trunk groups are as efficient as a regular graded group. Grading is explained in more detail in paragraph 7.

4.5 Example 1. This example illustrates a method of determining the number of inter-office trunks, based on traffic estimates.

4.51 In Sketch 1 trunk groups A-D, B-D and C-D are toll connecting trunks. Trunk groups A-B and B-C are EAS. EAS shall exist between A-B and B-C.

4.52 Calls between A and C shall be ticketed at the toll center, D.



SKETCH 1

4.53 Calling rates are as follows:

Direction and Terminating Points of Traffic	Subscribers		Average No. of Originating Messages (Busy Hour)			Average Originating Unit Calls** (Busy Hour)
	Office	No.	Per Subscriber		Total	
			EAS	Toll		
A - B	A	100	.02	-	2.00	3.00
A - C	A	100	-	.0025	.25	.75
A - D	A	100	-	.015 *	1.50	4.50
B - A	B	1500	.0012	-	1.80	2.70
B - C	B	1500	.006	-	9.00	13.50
B - D	B	1500	-	.024 *	36.00	108.00
C - A	C	500	-	.00045	.23	.69
C - B	C	500	.019	-	9.50	14.25
C - D	C	500	-	.022 *	11.00	33.00

* Calls to D include calls beyond the toll center, except for calls from A to C and C to A.

** Holding times: EAS - 150

1 These values may vary over depending upon calling hab toll center.

4.54 How many trunks are required in each of the five groups A-B, A-D, B-C, C-D, and D-B, assuming that toll traffic to the toll center and to exchanges outside the system is equal in either direction for toll groups?

4.55 Solution

4.551 It is to be noted that each item in the tabulation above considers traffic in one direction only. Where toll traffic to the toll center or to exchanges outside the system is considered, the number of unit calls is doubled to account for the total traffic in the group.

4.552 Group A-B will carry all traffic originating or terminating at A.

Direction of Traffic	Unit Calls
A - B	3.0
B - A	2.7
	5.7

4.553 Similarly, for other trunk groups

$$\frac{A - D}{4.5 \times 2 + .75 + .69} = 10.44 \text{ or } 10.4 \text{ unit calls.}$$

$$\frac{B - C}{13.5 + 14.25} = 27.75 \text{ or } 27.8 \text{ unit calls.}$$

$$\frac{C - D}{.75 + .69 + 2 \times 33.0} = 67.44 \text{ or } 67.4 \text{ unit calls.}$$

$$\frac{B - D}{2 \times 108} = 216 \text{ unit calls.}$$

4.554 The grades of service, in accordance with paragraph 3.24 are:

Group	EAS	Toll	No. of Miles	Grade of Service
A - B	x		11	.10
A - D		x	16	.05
B - C	x		10	.10
B - D		x	5	.03
C - D		x	9	.05
D - B		x	5	.03

4.555 Consider group A-B. The number of unit calls to be carried is 5.7 and P = .10. From Figure 2A for this grade of service:

No. of Trunks	No. of Unit Calls	Unit Calls Difference
1	3.8	15.3
2	19.1	

From paragraph 3.1,

10% x 15.3 = 1.53

If one trunk is to be provided, the maximum traffic which the group may carry is:

3.8 / 1.5 = 5.3

Since the number of unit calls to be provided for exceeds 5.3, the next higher trunk group is provided and,

N = 2. ANS. The grade of service is then P = .02.

4.556 In a similar manner, the number of trunks for each of the other groups is determined:

Group	Objective P	Unit Calls (Busy Hour)	No. of Trunks	Actual P
A - D	.05	10.4	2	.04
B - C	.10	27.8	3	.05
C - D	.05	67.4	5	.05
B - D	.03	216	*12	.02

5. LINEFINDER - CONNECTOR

5.1 A linefinder in a linefinder - connector system connects "back-to-back" with a local connector; the number of local connectors is therefore equal to the number of linefinders. The maximum number of lines and trunks in such a system is either 100 or 200, the so-called "broadspan" system being representative of the latter.

5.2 The number of linefinders
the number of lines per
criteria for the number
considered hereinafter.

* If this was the initial eight last choice 2-way rather than twelve 2-way

5.3 A linefinder group is a number of linefinders which serve a definite (or specific) group of subscriber lines having access to any one of the linefinders in the group. In offices large enough to require more than one linefinder group only part of the subscriber lines will be served by each linefinder group.

5.4 The usual number of lines having access to a linefinder group is 100 or 200, depending upon the type of equipment used. The advantage of using 200 line capacity linefinders is that, with the larger size, greater trunk efficiency is obtained and therefore fewer total linefinders will be required for an office; against this the supplier weighs the additional cost per linefinder and associated equipment where a linefinder having access to a larger number of lines is considered.

5.5 It is pertinent to mention that the grade of service rendered by a linefinder group is intimately associated with the percentage of line circuits equipped for lockout. A line which is shorted and is not equipped for lockout will hold a linefinder and connector out of service and thus effectively reduce the trunking efficiency of the group until cleared. This accounts for the difference in Columns G and H of Figure 1A.

5.6 Example 2. A central office proposal calls for 40 lines equipped initially and 60 lines equipped in ten years. The average originating busy hour unit calls per line is 2.4 initially and estimated to increase to 2.5 in ten years. All lines are equipped for lockout. Three bids are received.

5.61 The first provides six linefinder-connectors, the maximum number of links with which the switchboard may be equipped.

5.62 The second bid provides 6 links equipped and a maximum capacity of 10.

5.63 The third bid provides 7 links equipped and a maximum capacity of 10.

5.64 Which bidder has met the minimum requirements of the proposal from a traffic point of view?

5.65 Solution:

5.651 There are to be 40 lines equipped initially and 60 lines ultimately. The total number of originating unit calls which the equipment must handle is:

$$2.4 \times 40 = 96 \text{ unit calls}$$

initially and,

$$2.5 \times 60 = 150 \text{ unit calls}$$

ultimately.

5.652 Referring to Figure 1A, Column H, it is seen that seven linefinders must be provided initially and ten ultimately. Therefore, only the third bidder has met the specification. ANS.

6. LINEFINDER - SELECTOR - CONNECTOR

6.1 In the linefinder-selector-connector system the number of local first selectors is equal to the number of linefinders. The number of connector groups is determined by the number of lines if terminal-per-line operation is required or the number of main stations if each main station is assigned a connector terminal. The number of connectors is then determined for each group from the estimated traffic, both that from the office itself and that incoming from other offices.

6.2 In a linefinder-connector system, revertive calling (calling from one subscriber to another on the same line) is usually accomplished by dialing the listed directory number and no special level or terminal assignments are necessary. In systems involving selectors, revertive calling is often accomplished by dialing a special number. A level on the first selector or subsequent selector is reserved for revertive calling. This level connects to a group of revertive call switches.

6.3 Where an office is equipped for 100 percent lockout, the time that the revertive call switch is in use is only until the called station answers; where some of the lines in the office are not equipped for line lockout, it is necessary that the revertive call switch be held during the entire conversation time. The holding time associated with the revertive call switch group, therefore, depends upon whether all line circuits are equipped for lockout. It is generally assumed that approximately 5 percent of the unit calls originating on party lines are attributable to revertive traffic. This is the traffic load that should ordinarily be assumed where all lines are equipped for lockout. Five percent may be too low for some cases where the community of interest among subscribers on each rural line is high. As a general guide, however, two revertive call switches will usually be adequate for REA offices up to 300 lines. For offices larger than 300 lines, the estimate of revertive traffic should be made after analysis of local conditions. Where the office is equipped for 100 percent lockout, the unit calls for revertive traffic should be multiplied by 15 percent to obtain the load on the revertive call switch group.

6.4 Example 3. A switchboard is to be equipped with 160 lines and all lines are to be equipped with the line lockout feature. The average originating busy hour unit calls per line is 2.0.

6.41 (a) How many linefinders are required if the maximum number of lines per linefinder group is 100 and 100 lines are in one group and 60 lines are in the other?

6.42 (b) How many if the maximum number of lines per linefinder is 200?

6.43 (c) How many if the maximum number of lines per linefinder is 100 and 80 lines are in each group?

6.44 Solution

6.441 (a) The number of unit calls to be carried by each linefinder group is,

100 x 2.0 = 200 unit calls
60 x 2.0 = 120 unit calls

Referring to Figure 1A, Column H, it is seen that 11 trunks will carry 192 unit calls and 12 trunks will carry 218 unit calls. Therefore, 12 trunks are required for the 100 line group. From the table, the 120 unit calls for the partial linefinder group will require the provision of 8 linefinders. The total number of linefinders is 20. ANS.

6.442 (b) If all lines may be included in one group,

160 x 2.0 = 320 unit calls

are carried by that group. Referring to Figure 1A, Column H, it is seen that 15 trunks will carry 296 unit calls and 16 trunks 324 unit calls. The number of linefinders required is therefore 16. ANS.

6.443 (c) If the lines are in two equal groups,

80 x 2.0 = 160 unit calls

are carried in each group. Referring to Figure 1A, Column H, it is seen that 10 trunks will carry 168 unit calls. The number of linefinders required is 2 x 10 = 20. ANS.

6.5 Example 4. This example illustrates an office having a low calling rate per line. In Example 5, a high calling rate per line for the same office is illustrated.

6.51 A step-by-step switchboard specification reads as follows:

	Number	Originating Busy-Hour Unit Calls Per Line
Individual Lines	60	1.2
Party Lines	240	1.5
Two-way Operator Office Trunks	8	-

6.52 Five percent of all traffic originating on party lines is revertive and no lines are equipped for lockout. Traffic on inter-office trunks is equal in either direction.

6.53 Calculate the number of groups and switches per group for the following equipment:

(a) Linefinders (100 lines per group)*

(b) Local first selectors

(c) Incoming selectors

(d) Connectors (terminal per line)

(e) Revertive call switches

6.54 Solution (Refer to Figure 6)

6.5401 (a) Since there are 300 lines in the central office and 100 lines per group, 3 linefinder groups are required. ANS.

6.5402 Twenty individual lines and eighty party lines are assigned to each group. Therefore, the unit calls per linefinder group are:

$20 \times 1.2 = 24$

$80 \times 1.5 = \underline{120}$

Unit Calls = 144

*Two groups of 200 line linefinders may prove economical in an office of this size in some cases.

Referring to Figure 1A, Column G, it is seen that 9 trunks will carry 126 unit calls and 10 trunks 149 unit calls. Ten linefinders per group are therefore required.

3 x 10 = 30 linefinders. ANS.

6.5403 (b) The number of local first selectors is the same as that for the linefinders. ANS.

6.5404 (c) Each two-way trunk requires an incoming selector; 8 will, therefore, be required. ANS.

6.5405 (d) One hundred lines shall be served from each of three selector levels. There are, therefore, 3 connector groups.

6.5406 In Figure 6, it is assumed that first selector levels 2, 3 and 4 are to be used for connector groups serving subscriber lines. The number of trunks from selector level 2 to the "200" group of connectors depends on the number of unit calls which are incoming to the connectors. In this case there are two classes of calls which originate in the exchange and which are not incoming to the local connectors: calls to the operator office and revertive calls.

6.5407 It is stated that in this office traffic on inter-office trunks is equal in either direction. Therefore, there is as much traffic from the operator office which will be incoming to local connectors as there is traffic originating in local first selectors which will not go to connectors. The net effect of the operator office trunk group on traffic to local connectors is therefore zero.

6.5408 A different selector level, say 5, will be assigned to revertive call switches and, since 5 percent of all calls originating on party lines are revertive calls,

.05 x 1.5 = .075

unit calls per line are revertive calling. This means that

80 x .075 = 6

unit calls for this group of 100 lines will not go to the 200 line connector group. The total

number of unit calls to the connector group, adjusted for revertive calls is,

144 - 6 = 138 unit calls.

6.5409 Referring to Figure 1A, Column J, it is seen that 9 connectors are required in the 200 line group. Similarly, 9 will be required in both the 300 and 400 line group or a total of 27. ANS.

6.5410 (c) The total number of unit calls to be handled for the party lines by revertive call switches is 240 x .075 = 18 unit calls. Referring to Figure 2A, P = .01, it is seen that 4 revertive call switches are required. Since access to these will all be from first selector level 5, they will be in one group. ANS.

7. GRADED MULTIPLE

7.1 Grading is normally done by the switchboard supplier but an understanding of it is required for satisfactory C.O.E. acceptance testing and it can result in the design of a lower cost system with improved traffic handling capabilities. It will also be valuable when rearrangements are necessary because of unanticipated traffic. It is important that trunks from selector levels be arranged in such a manner that they will operate at the maximum possible efficiency as far as call carrying capacity is concerned, and at the same time furnish the required grade of service. Most selectors have access to not more than ten trunks on each of its ten levels. The bank multiple for a shelf of ten selectors is common and therefore all ten selectors use the outgoing trunks for each of the ten levels in common. Should more than ten trunks be required from a level of selectors, the trunks are usually arranged in what is called a graded multiple group and the ten or less selectors mounted on each shelf will have access to only ten of the trunks.

7.2 Any one of the ten lev
selectors can be arran
trunks. This is accom
terminals of one or mo
one to five, usually.
two or more similar fi
individual trunks. Th
not used for the above
with trunks which are
trunks will, therefore
finds all the trunks i

The following formula can be used to determine the number of individual trunks in each leg of the grade:

$$\text{Number of Individual Trunks for each Leg} = \frac{\text{Number of Trunks} - \text{Trunks Per Level}}{\text{Number of Legs} - 1}$$

The greater the number of legs in the grade the greater the efficiency up to about six or seven legs. Due to the physical limitations it will not always be possible to have the most efficient grade. With the usual ten trunk access per level switch the preferred number of common trunks is five or more.

7.3 The simplest graded multiple arrangement of trunks from a level of selectors would be the case of twenty selectors, arranged on two shelves (two legs) of ten selectors each, before eleven trunks. This is represented by Figure 4, $\frac{11 - 10}{2 - 1} = 1$. The first shelf of ten selectors would be given access to ten trunks, but the last nine of these trunks would be multipled to the corresponding nine terminals of the second shelf of ten selectors. The second ten selectors would be provided with a trunk assigned to the first terminal for their exclusive use (shown as trunk 11 in Figure 4) as the first choice trunk. When one of these ten selectors has a call and finds its first choice trunk busy it hunts over the remaining nine trunks shared in common with the other ten selectors. Each leg of the grade therefore, has one first choice individual trunk and nine common trunks. Due to an REA requirement most manufacturers provide rotatio over the first three trunks on each level which tends to reduce the efficiency if they are common to other legs of the grade.

7.4 In actual practice the number of selectors to be multipled before a graded group of trunks for a level will vary and so will the number of trunks in the grade depending on the size of the office and the volume of traffic to be routed from a selector level. Some additional cases are shown in Figure 5 and in Examples 5 and 6.

7.5 As a comparison of the trunking efficiency with three arrangements of trunks the following is of interest:

From Figure 3, for P = .02 it will be noted that one group of 18 trunks having full access will carry 10 erlangs (360 unit calls). In Figure 2A, for P = .02 a graded group of 18 trunks will carry 341 unit calls with ten point access switches. Again referring to Figure 2A, for P = .02, 18 trunks arranged in two subgroups of 9 trunks each will carry

2 x 142 = 284 unit calls.

This comparison indicates that where there is a choice of trunking arrangements they should in general be selected, first for full access, then for graded multiple, and last subgrouping, to take advantage of the relatively greater trunking efficiency.

7.6 Consider a situation where 288 unit calls (8 erlangs) are to be carried from one level of a group of second selectors to connectors with P = .01.

7.61 Assume that any number of trunks may be busy-tested on a level of a group of selectors (full access). From Figure 3 (P = .01), it is seen that 17 trunks to one connector group will be required.

7.62 If a maximum of ten trunks may be busy-tested on a level of a selector where no grading is employed, from Figure 2A, P = .01, it is seen that 10 trunks will carry 149 unit calls. Two subgroups of 10 trunks each carrying a total of 298 unit calls are necessary.

7.63 If grading is employed with the type of selectors in paragraph 7.62, then from Figure 2A, P = .01, it is seen that 18 trunks in a graded group will carry 310 unit calls.

7.64 A qualitative representation of connections in the arrangement of paragraph 7.62 is shown in Figure 5A. The arrangement for paragraph 7.63 is shown in Figure 5B. It should be borne in mind that all terminals shown in each figure appear on the same level among all the selectors in each group.

7.65 In Figure 5A, half the second selectors have the terminals of this level multipled and going to one subgroup of connectors as trunks 1 to 10 in subgroup 1, and the other second selectors have the terminals of the same level multipled and going to another subgroup of connectors as trunks 11 to 20 in subgroup 2. Theory, borne out by actual tests, indicates that when trunks are always tested in order, beginning with No. 1, the last few will carry very little traffic. Experience has shown that their load can be raised by giving both subgroups access to these last-choice trunks without materially increasing the calls lost. This, of course, increases the efficiency of the group as a whole.

7.66 In Figure 5B, those selectors which have connection to trunks 1 to 4 do not have access to trunks 11 to 18, but all selectors have access to trunks 5 to 10. It is this full availability of the last busy-tested trunks on the level which makes it possible to carry the same traffic with 18 trunks using grading as with 20 not using grading. It is the fact that there is full availability of only 6 trunks which makes it necessary that there be 18 trunks using grading instead of 16 if grading were unnecessary.

7.7 Example 5. This example is the same as Example 4, except for the higher originating calling rate which requires the use of graded multiple for trunks from first selectors to connectors.

The traffic specification for a switchboard is as follows:

	Number	Originating Busy-Hour Unit Calls Per Line
Individual Lines (including paystations)	60	1.6
Party Lines	240	2.5
Two-Way Operator Office Trunks	8	-

7.71 Five percent of all calls originating on party lines is revertive traffic and no lines are equipped for lockout. Traffic on inter-office trunks is 142 unit calls with equal traffic in both directions. Each first selector may search over a maximum of ten trunks per level and selector shelves have a capacity of 10 selectors.

7.72 Calculate the number of groups and the switches per group for the following:

(a) Linefinders (100 lines per group)*

(b) Local first selectors

(c) Incoming selectors

(d) Connectors (terminal per line)

(e) Revertive call switches

7.73 Solution (Refer to Figure 7).

7.731 (a) Since there are 300 lines in the central office and 100 lines per group, 3 linefinder groups are required. ANS.

*200 line linefinders may prove economical in an office of this size.

7.732 Twenty individual lines and eighty party lines are assigned in each of the three groups. Therefore, the unit calls per linefinder group are:

20 x 1.6 = 32

80 x 2.5 = 200

Unit Calls 232

Figure 1A, Column G, is used since all lines are not equipped for lockout. It is seen that 14 linefinders per group are required or

3 x 14 = 42 linefinders. ANS.

7.733 (b) The number of first selectors is the same as the number of linefinders there will probably be. Three shelves of 8, and 2 shelves of 9. ANS.

7.734 (c) Each two-way trunk requires an incoming selector; one group of 8 will therefore be required. ANS.

7.735 (d) A maximum of 100 lines, one connector group, shall be served from each of three selector levels. There are therefore three connector groups. ANS.

Assume that each of the first selector levels 2, 3 and 4 is assigned to a group of connectors. The number of trunks from selector level 2 to the "200" group of connectors depends on the number of unit calls which are incoming to the connectors as in Example 4.

Assume that level 5 goes to revertive call switches. Since 5 percent of the unit calls on party lines are revertive calls,

.05 x 2.5 = .125 unit calls

per line are revertive calling.

The total number of unit calls to the "200" connector group, adjusted for revertive calls, and the fact that incoming trunk traffic equals outgoing, is,

232 - (80 x .125) = 222 unit calls.

Referring to Figure 1A, Column J, it is seen that 13 connectors are required for the 222 unit calls. Similarly, 13 connectors will be required in each of the "300" and "400" groups or a total of

3 x 13 = 39 connectors. ANS.

One-third of the incoming toll traffic, (1/3 x 71) = 27 unit calls, terminates in each connector group. Each of the five groups of local first selectors offer approximately 1/5 (232 - 10 - 27) = 39 unit calls to each connector group. There are six (5 local and 1 toll) shelves of selectors. This should be divided into as many groups as it takes to give approximately 5 commons. The number of legs can conveniently be 6 of one shelf each, 3 of two shelves each, or 2 of three shelves each.

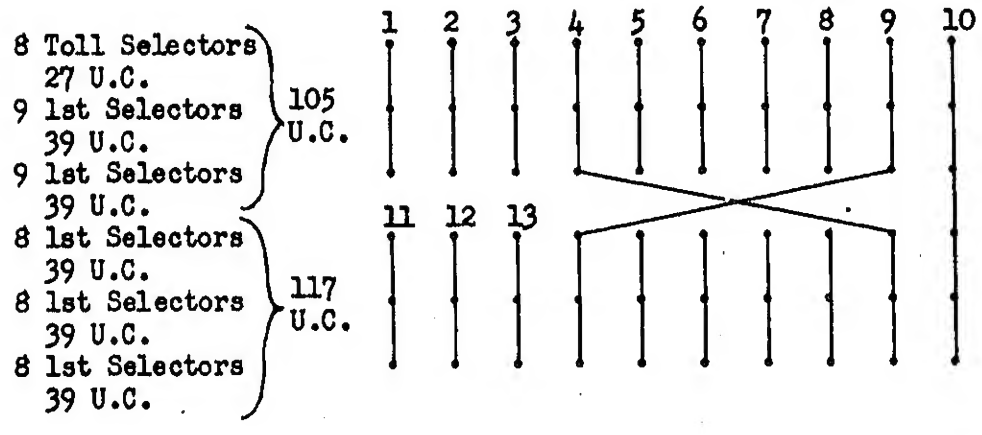
The number of individual trunks for each arrangement is as follows:

$$\frac{13 - 10}{6 - 1} = 0.6; \qquad \frac{13 - 10}{3 - 1} = 1.5;$$

$$\frac{13 - 10}{2 - 1} = 3$$

A desirable pattern for grading each group of 13 connectors before the six shelves of selectors is as follows:

*



* Trunks 1, 2 and 3 are picked in rotation as are 11, 12 and 13, even though the first choice trunks may actually be idle.

7.736 (e) The total number of unit calls to be carried by revertive call switches is:

$$240 \text{ lines} \times .125 \frac{\text{unit calls}}{\text{line}} = 30 \text{ unit calls}$$

From Figure 2A, P = .01, it is seen that 4 revertive call switches are required. ANS.

8. LINEFINDER - 1st SELECTOR - 2nd SELECTOR - CONNECTOR

8.1 When the total number of trunk groups from first selectors exceeds ten, second selectors and infrequently third selectors may be required as there are but ten levels available for trunk groups from first selectors.

8.2 The flexibility made possible by such an arrangement sometimes makes the use of terminal per station (TPS) and terminal per line (TPL) connectors in the same office desirable. It is generally advisable to include in a traffic specification not only originating but terminating busy-hour traffic in order that the proper amount and arrangement of each type of equipment may be determined.

8.3 Example 6. The traffic data in a central office specification contains the following information:

Estimated Initial Originating Traffic (B-H)

		Terminal Per Line				Terminal Per Station			
		a	b	a x b		e	f	e x f	
Class of Service		Unit Calls Per Main Station	No. of Main Stations	Total U.C. by Class of Service	No. of Lines	Unit Calls Per Main Station	No. of Main Stations	Total U.C. by Class of Service	No. of Lines
One Party (Excl.PBX)	B					1.5	40	60	40
	R					1.0	50	50	50
Two Party	B					1.2	60	72	33
	R					0.8	100	80	56
Four Party	B					-			
	R					0.6	220	132	61
Eight Party		0.4	1000	400	139				
Pay-station						1.5	4	6	4
PBX						4.0 *	6 **	24	6
Official Lines						2.0	2	4	2
Wire Chief						2.0	1	2	1
	Total		1000	400 (c)	139 (d)	Total	483 (k)	430 (h)	253 (j)

* This figure is the calling rate per PBX (PABX) trunk.

** This figure is the number of PBX (PABX) trunks.

Outgoing Inter-Office Traffic (B-H)		
Inter-office Trunk Group	Two-way - to operator Office "X"	Two-way - to EAS Office "Y"
Service	Toll & Assistance	EAS
Distance to other office (mi.)	6	7
Unit Calls/main station[1]	.08	.11
Total Main Stations	1483	1483
Total Unit Calls	119	163

[1] These should be derived from data on the existing system.

8.301 Five percent of all originating traffic on party lines is reverting, and revertive call switches shall be used. All lines are equipped for lockout. Fifteen percent of revertive call traffic is carried by revertive call switches (from receiver off until the called party answers).

8.302 Due to the initial percentage of 2 and 4 party stations and the anticipated growth, it is determined that 1, 2 and 4-party and paystation service shall be provided by terminal per station (TPS) connectors and 8-party service by terminal per line (TPL) connectors.

8.303 The distance to offices X and Y indicate that a grade of service of P = .03 is to be rendered on operator office trunks and P = .05 on EAS trunks. Linefinder groups shall be arranged for a maximum of 200 lines. All switches shall be the 10 point access per level type and selector shelves shall have a capacity of 10 selectors.

8.304 The first selector level assignments shall be as follows:

Level	To
0	Operator office trunks to office X
9	Paystation (mult. to level 2)
8	EAS trunks to office Y
7	Revertive call switches
6	Unassigned
5	Unassigned
4	TPL connectors
3	TPL connectors
2	2nd selectors for TPS
1	Unassigned

8.305 Levels 1 through 5 of the second selectors shall be assigned to TPS connectors and levels 6 to 0 shall be unassigned.

8.306 Verification shall be obtained from a special group of switches off level 0 of the incoming operator office trunk first selectors.

8.307 Incoming and outgoing traffic in inter-office trunk groups are approximately equal.*

8.308 Determine the quantities and grouping arrangements of the following equipment:

(a) Linefinders

(b) Local first selectors

(c) Incoming first selectors for operator office trunks

(d) Incoming first selectors for EAS trunks

(e) Revertive call switches

(f) TPL connectors

(g) Second selectors

(h) TPS connectors

8.309 Indicate by notes the multipling, grading, and trunking arrangements to be provided and show the flow of traffic to and from the various switching stages by means of a traffic diagram.

8.310 Solution (Refer to Figure 8)

8.3101 (a) From items d and j of the traffic specification for this office a total of

$$139 + 253 = 392 \text{ lines}$$

are required in this central office. Since each linefinder group has a capacity of 200 lines, 2 groups are required. The first shall have **200 working lines and the second 192 working lines. ANS.

From items c and h, the average originating traffic per line is,

$$\frac{400 + 430}{392} = 2.12 \frac{\text{unit calls}}{\text{line}}$$

* It should not be inferred from this example that this is necessarily true in all cases, however.

** It may be impossible for some suppliers t working lines in the group because of

The traffic to linefinder Group I is,

200 x 2.12 = 424 unit calls.

That to Group II is,

192 x 2.12 = 407 unit calls.

From Figure 1A, Column H, it is seen that Group I should be equipped with 20 linefinders and Group II with 19 linefinders or a total of 39. ANS.

8.3102 (b) The number of local first selectors is the same as the number of linefinders. They will be arranged in three groups of 10 and one group of 9.

8.3103* (c) Level 0. The total traffic to be carried by the trunks between this office and office X is twice the originating traffic since it is equal in both directions:

2 x 119 = 238 unit calls.

The grade of service being .03, a need of more than 10 trunks (the maximum which can be fully accessed from one level of a selector) is indicated in Figure 2A. From this figure, N = 13, arranged in a graded group. If one leg of the grade is in each office, seven 2-way and six 1-way trunks will be the most economical.

8.3104* (d) Level 8. In a similar manner, the traffic to be carried by EAS trunks to office Y is,

2 x 163 = 326 unit calls.

P = .05, and from Figure 3,

N = 16. ANS.

If one leg of the grade is in each office, four 2-way and twelve 1-way trunks will be the most economical. If two shelves are available in each office for these selectors, eight 2-way and eight 1-way trunks (four legs in the grade) would be more efficient from a traffic standpoint.

* These are examples of how understanding grading can help reduce costs. One and possibly two selector shelves are saved by specifying 2-way and 1-way trunks rather than all 2-way trunks.

8.3105 (e) Level 7. The total amount of originating traffic on party lines is:

Class of Service	Unit Calls
2P Business	72
2P Residence	80
4P	132
8P	400
Total	684

The C. O. specifications define originating traffic as that which is offered to linefinder equipment.

Since 5 percent of party line traffic is revertive, and with 100 percent lockout revertive call switches are held for 15 percent of that time, the percentage of originating traffic holding revertive call switches is:

.05 x .15 = .0075 or 0.75%

The traffic carried by revertive call switches is:

.0075 x 684 = 5.13 or 5 unit calls.

From Figure 2A, P = .01, 2 revertive call switches are required. ANS.

8.3106 (f) Level 2. The total traffic to second selectors for the five groups of terminal per station connectors will be the same as the originating traffic as shown in item (h), except that the 430 originating unit calls includes traffic to revertive call switches.

The traffic to TPS second selectors, adjusted for revertive calls, is,

430 - (284 x .0075) = 428 unit calls.

From Figure 1A, Column L,

N = 22 ANS.

Approximately one-half $\frac{430}{830}$ of the incoming toll and EAS traffic is offered to these TPS second selectors.

Toll $\frac{430}{830}$ x 119 = 61.5 unit calls

EAS $\frac{430}{830}$ x 163 = 84.5 unit calls

The average local TPS traffic handled by each local first selector is 1/39 (428 - 61.5 - 84.5) = 72.3 unit calls.

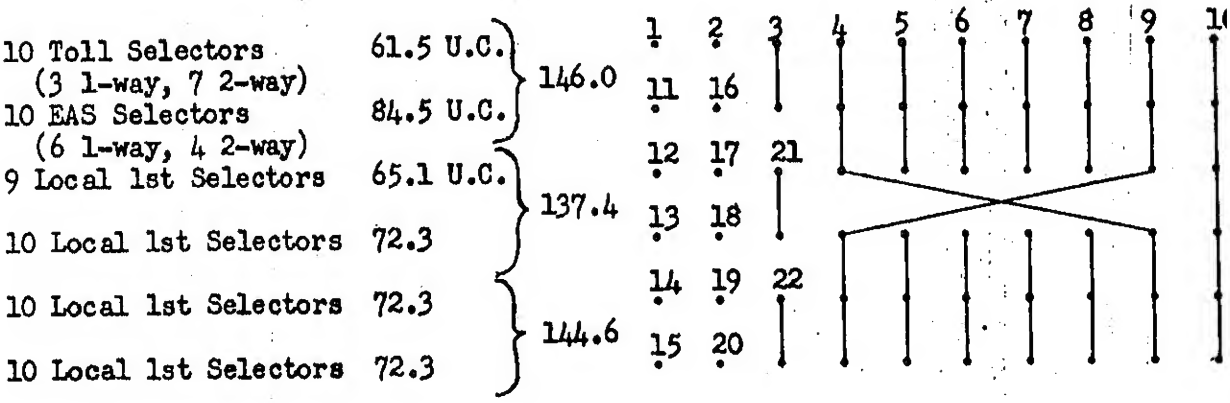
There are six (4 local, 1 EAS and 1 toll) shelves of selectors. Because the traffic from each shelf is about equal, six, three and two legs should be checked in arriving at a desirable grading pattern.

The number of individual trunks for each arrangement is:

$\frac{22 - 10}{6 - 1}$ = 2.4; $\frac{22 - 10}{3 - 1}$ = 6;

$\frac{22 - 10}{2 - 1}$ = 12

Six legs will give the most desirable grade.



NOTE: TPS selectors 1, 2 and 3 are picked in rotation as are 11, 16 and 3; 12, 17 and 21; 13, 18 and 21; 14, 19 and 22; and 15, 20 and 22.

8.3107 (g) The number of groups of TPS connectors is (from item K of the traffic specification)

$$\frac{483}{100} = 4.83 \text{ or } 5 \text{ groups.} \quad \text{ANS.}$$

There will be 4 groups of 100* working terminals each and one group of 83 working terminals. All the traffic to second selectors will terminate in one of these five groups. The average traffic per main station is,

$$\frac{428}{483} = 0.89 \frac{\text{unit calls}}{\text{main station}}$$

Groups I to IV each will carry

$$0.89 \times 100 = 89 \text{ unit calls.}$$

From Figure 1A, Column K, N = 8 for each group.

Group V will carry

$$0.89 \times 83 = 74 \text{ unit calls.}$$

For this group, N = 7. The total number of terminal per station connectors is therefore

$$4 \times 8 \neq 7 = 39. \quad \text{ANS.}$$

8.3108 (h) Levels 3 and 4. Column "d" of the traffic specification for this office shows a total of 139 lines terminated on TPL connectors. Therefore 2 groups will be required. ANS.

Group I shall terminate 100** lines and Group II 39 lines.

The average originating traffic per line is found from items (c) and (d) to be,

$$\frac{400}{139} = 2.88 \frac{\text{unit calls}}{\text{line}}$$

* It may be impossible for suppliers to have 100 working terminals because of test requirement.

** It may be impossible for suppliers to have 100 working lines in the group because of test requirements.

Of this traffic 0.75%, or .02 unit calls per line goes to revertive call switches. The remainder

$$2.86 \ \frac{\text{unit calls}}{\text{line}}$$

is equal to the amount of traffic terminating on the TPL connectors.

Group I will therefore carry

$$2.86 \times 100 = 286 \text{ unit calls}$$

From Figure 1A, Column J, N = 16.

$$\frac{16 - 10}{6 - 1} = 1.2; \qquad \frac{16 - 10}{3 - 1} = 3;$$

$$\frac{16 - 10}{2 - 1} = 6$$

In a manner similar to that shown for the TPS selectors this grade would have three legs with seven connectors common and three connectors individual to each leg.

Group II will carry

$$2.86 \times 39 = 112 \text{ unit calls}$$

and N = 8. The total number of terminal per line connectors is therefore 24. ANS.

TRUNK CAPACITY TABLES FOR INTRA-OFFICE TRUNKS
(10 Terminal Access)

Number Trunks Per Group	Unit Calls: Linefinders: Less Than 100 Percent Line Lockout -G-	Unit Calls: Linefinders: 100 Percent Line Lockout -H-	Unit Calls: Line-Finder Connectors -H-	Unit Calls: Connectors From: 1st Sels. -J-	Unit Calls: Connectors From: 2nd Sels. -K-	Unit Calls: Trunks to Second Selectors -L-	Number Trunks Per Group
3	16	20	20	24	16	20	3
4	30	37	37	42	30	37	4
5	46	55	55	62	46	56	5
6	64	77	77	85	64	76	6
7	84	98	98	105	84	97	7
8	105	122	122	129	105	119	8
9	126	144	144	153	126	142	9
10	149	168	168	176	149	166	10
11	172	192	192	199	168	194	11
12	195	218	218	220	187	216	12
13	220	242	242	242	205	236	13
14	244	270	270	262	223	257	14
15	269	296	296	284	241	278	15
16	294	324	324	305	259	299	16
17	320	352	352	327	276	319	17
18	346	380	380	347	294	341	18
19	373	408	408	367	312	363	19
20	399	436	436	387	329	385	20
21	426	462	462	406	347	408	21
22	453	494	494	425	364	429	22
23	480	520	520	444	382	451	23
24	507	550	550	463	399	473	24
25	535	580	580	483	417	495	25
26	562	610	610	503	435	516	26
27	590	640	640	523	453	537	27
28	618	670	670	542	470	558	28
29	647	700	700	562	488	579	29
30	675	730	730	582	506	600	30
					Graded		

FIGURE 1A

TRUNK CAPACITY TABLES FOR INTRA-OFFICE TRUNKS
(15 Terminal Access)

Number Trunks Per Group	Unit Calls: Linefinders: Less Than 100 Percent Line Lockout -G-	Unit Calls: Linefinders: 100 Percent Line Lockout -H-	Unit Calls: Line-Finder Connectors -H-	Unit Calls: Connectors From: 1st Sels. -J-	Unit Calls: Connectors From: 2nd Sels. -K-	Unit Calls: Trunks to Second Selectors -L-	Number Trunks Per Group
3	16	20	20	24	16	20	3
4	30	37	37	42	30	37	4
5	46	55	55	62	46	56	5
6	64	77	77	83	64	76	6
7	84	98	98	105	84	97	7
8	105	122	122	129	105	119	8
9	126	144	144	153	126	142	9
10	149	168	168	178	149	166	10
11	172	192	192	204	172	198	11
12	195	218	218	230	195	226	12
13	220	242	242	256	220	253	13
14	244	270	270	283	244	281	14
15	269	296	296	310	269	310	15
16	294	324	324	335	290	335	16
17	320	352	352	360	312	361	17
18	346	380	380	385	334	386	18
19	373	408	408	408	355	411	19
20	399	436	436	430	376	436	20
21	426	462	462	453	397	461	21
22	453	494	494	476	417	485	22
23	480	520	520	498	437	511	23
24	507	550	550	521	457	536	24
25	535	580	580	544	477	563	25
				Graded			

FIGURE 1B

TRUNK CAPACITY TABLE IN CCS OR UNIT CALLS
(For Use With 10 Terminal Access Switching Equipment)

N = Number of Trunks	P = Grade of Service									
	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10
1	.4	.7	1.1	1.5	1.9	2.2	2.6	3.0	3.4	3.8
2	5.4	7.9	9.7	11.3	12.9	14.2	15.6	16.8	18.0	19.1
3	15.7	20.4	24.0	26.9	29.4	31.7	33.9	35.9	37.8	39.6
4	29.6	36.7	41.6	45.7	49.1	52	55	58	60	63
5	46.1	55.8	61.6	66.6	70.9	75	78	81	85	88
6	64.4	76.0	82.8	89.3	94.1	99	103	107	110	115
7	83.9	96.8	105	112	118	123	128	132	136	140
8	105	119	129	137	145	149	154	159	163	168
9	126	142	153	162	169	175	181	186	191	196
10	149	166	178	188	195	202	208	214	219	224
--	--	194	208	217	224					
		216	230	238	246					
		236	252	260	269					
		257	274	284	293					
		278	296	308	318					
		299	318	332	343					
		319	340	356	368					
		341	362	380	392					
		363	385	403	416					
		385	408	427	441					
		408	431	450	465					
		429	452	473	489					
		451	478	498	514					
		473	500	521	538					
		495	522	545	563					
		22	22	24	25					

Graded Multiple

FIGURE 2A

TRUNK CAPACITY TABLES IN CCS OR UNIT CALLS
(For Use With 15 Terminal Access Switching Equipment)

N = Number of Trunks	P = Grade of Service									
	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10
1	.4	.7	1.1	1.5	1.9	2.2	2.6	3.0	3.4	3.8
2	5.4	7.9	9.7	11.3	12.9	14.2	15.6	16.8	18.0	19.1
3	15.7	20.4	24.0	26.9	29.4	31.7	33.9	35.9	37.8	39.6
4	29.6	36.7	41.6	45.7	49.1	52	55	58	60	63
5	46.1	55.8	61.6	66.6	70.9	75	78	81	85	88
6	64.4	76.0	82.8	89.3	94.1	99	103	107	110	113
7	83.9	96.8	105	112	118	125	128	132	136	140
8	105	119	129	137	143	149	154	159	163	168
9	126	142	153	162	169	175	181	186	191	195
10	149	166	178	188	195	202	208	214	219	224
11	172	191	204	214	222					
12	195	216	230	240	249					
13	220	241	256	267	277					
14	244	267	283	295	305					
15	269	293	310	322	333					
16	310	335	352	364	375					
17	334	361	379	391	403					
18	357	386	404	420	430					
19	382	411	431	444	457					
20	405	436	456	471	483					
21	429	461	483	497	510					
22	451	485	507	523	537					
23	475	511	534	550	564					
24	498	536	560	576	591					
25	525	563	587	604	620					
Additional CCS for Each Trunk Over 25	27	27	27	27	29					

Graded Multiple Above 15 Trunks

FIGURE 2B

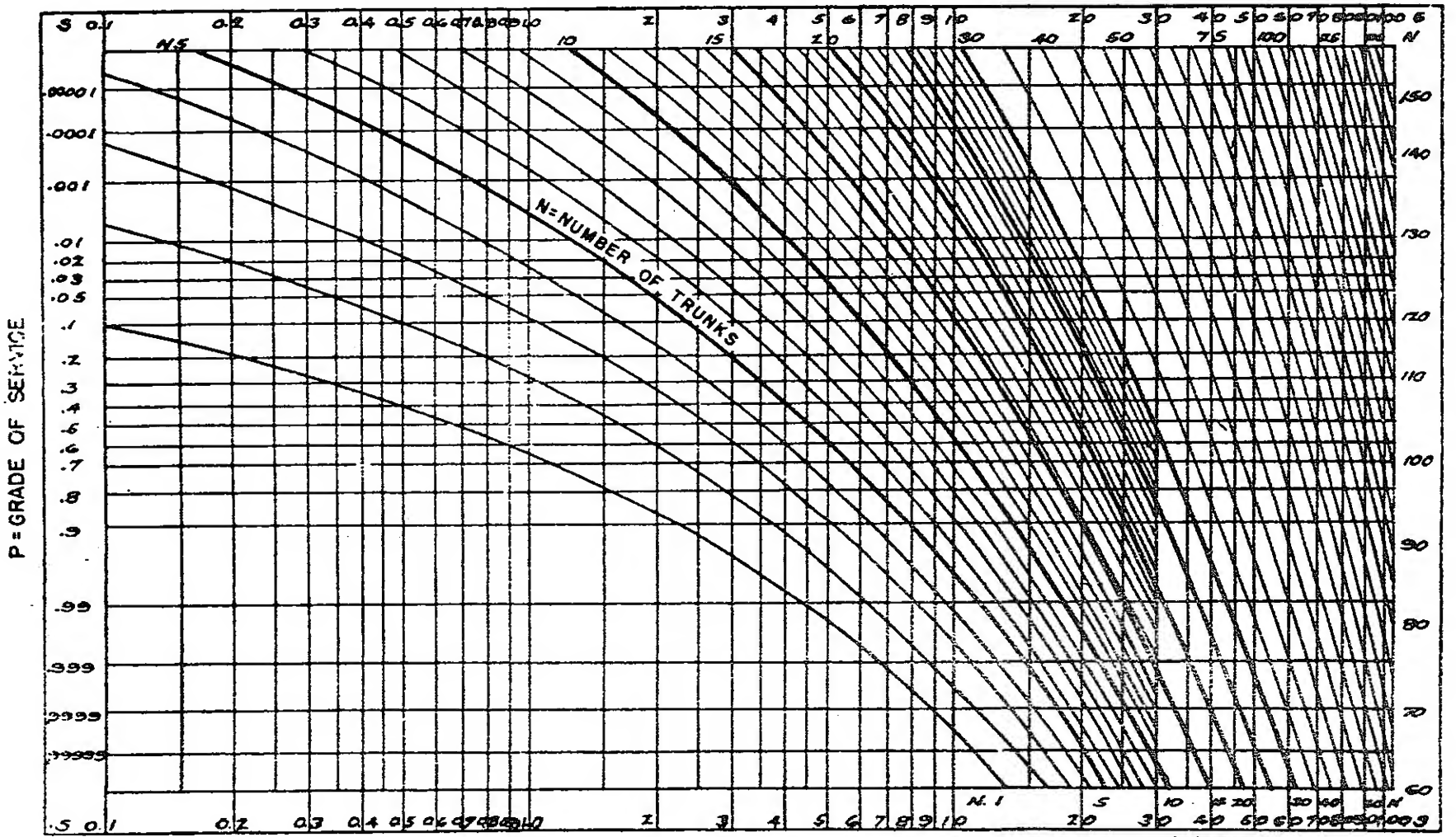
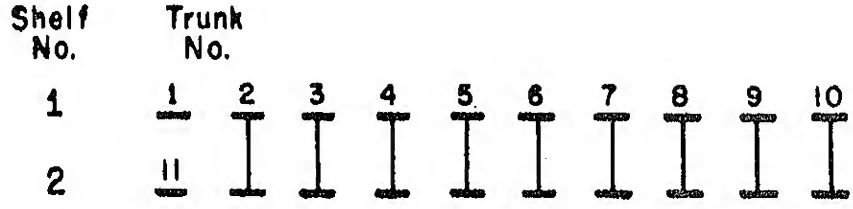


FIGURE 3 - THE PROBABILITY CURVE

(FULL AVAILABILITY ASSUMED)

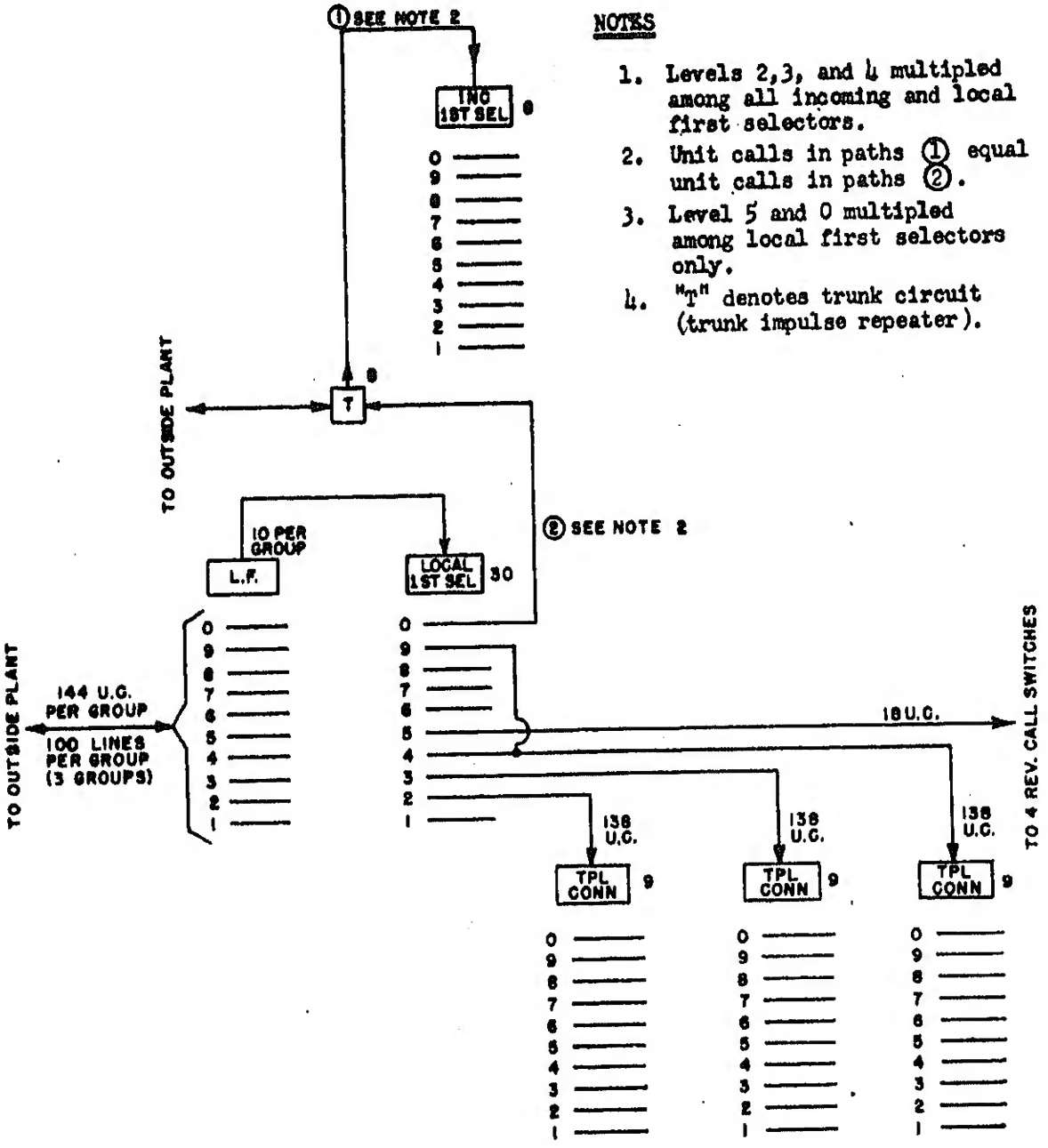
METHOD OF GRADING THE SAME LEVEL OF TWO SHELVES BEFORE ELEVEN TRUNKS

(Subgroup of 11 trunks, two legs of the grade)



Due to an REA requirement that during light traffic the equipment will use three different paths on three successive calls, trunks 1 (or 11), 2 and 3 will be picked in rotation.

Figure 4



NOTES

1. Levels 2,3, and 4 multipled among all incoming and local first selectors.
2. Unit calls in paths ① equal unit calls in paths ②.
3. Level 5 and 0 multipled among local first selectors only.
4. "T" denotes trunk circuit (trunk impulse repeater).

Figure 6
TRAFFIC DIAGRAM-EXAMPLE 4

COMPARISON OF MULTIPLING ARRANGEMENTS WITH AND WITHOUT GRADING

A. NO GRADING (2 Subgroups 10 trunks each)

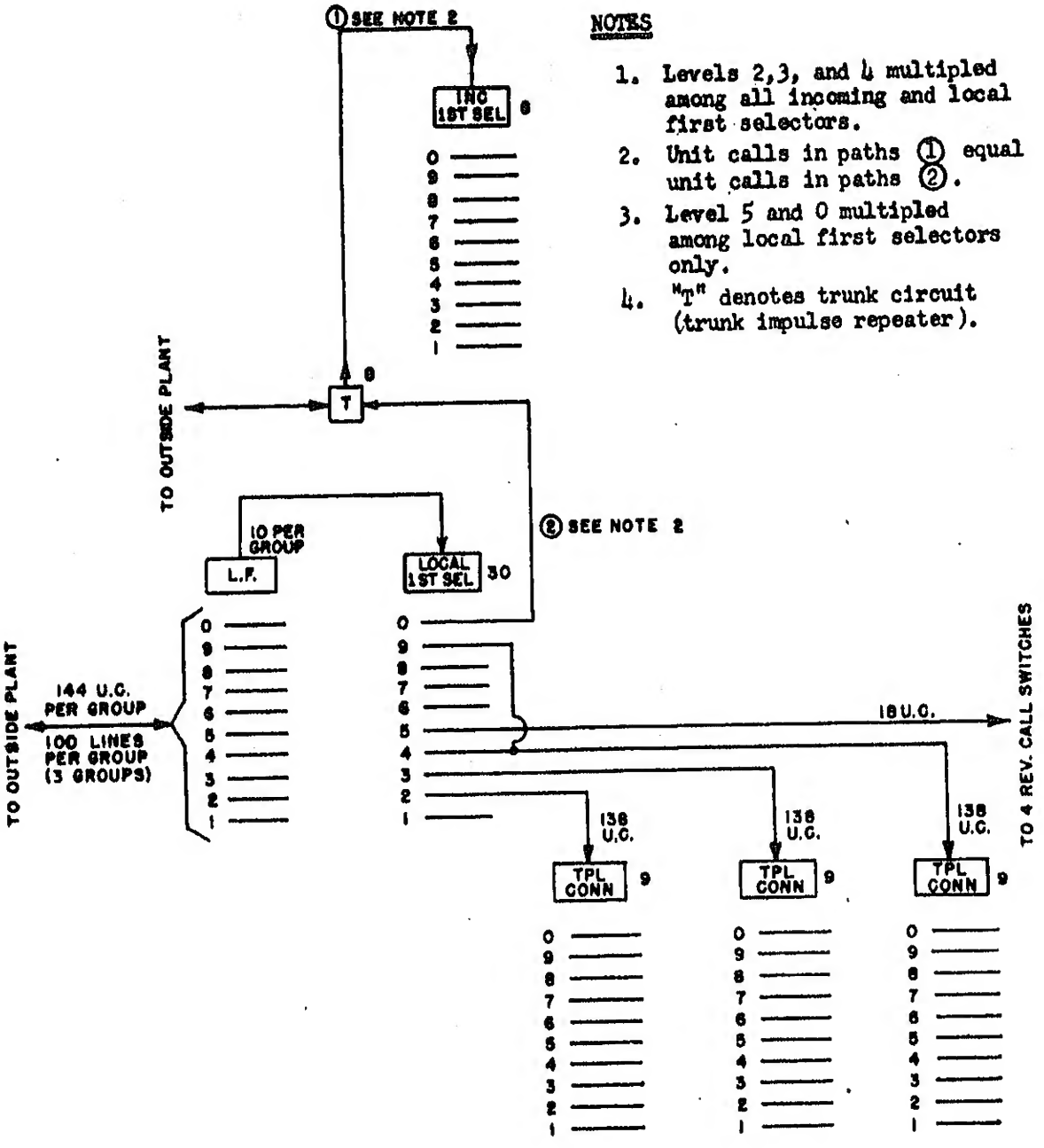
Subgroup	Trunk No.									
1	1	2	3	4	5	6	7	8	9	10
2	11	12	13	14	15	16	17	18	19	20

B. GRADING (1 Subgroup of 18 trunks, three legs of the grade)

Leg	Trunk No.									
A	1	2	3	4	5	6	7	8	9	10
B	11	12	13	14						
C	15	16	17	18						

A subgroup (or a leg of the grade) may consist of one or more shelves of selectors. Trunks 1, 2 and 3 are picked in rotation as are 11, 12 and 13, and 15, 16 and 17.

Figure 5



NOTES

1. Levels 2,3, and 4 multipled among all incoming and local first selectors.
2. Unit calls in paths ① equal unit calls in paths ②.
3. Level 5 and 0 multipled among local first selectors only.
4. "T" denotes trunk circuit (trunk impulse repeater).

Figure 6
TRAFFIC DIAGRAM-EXAMPLE 4

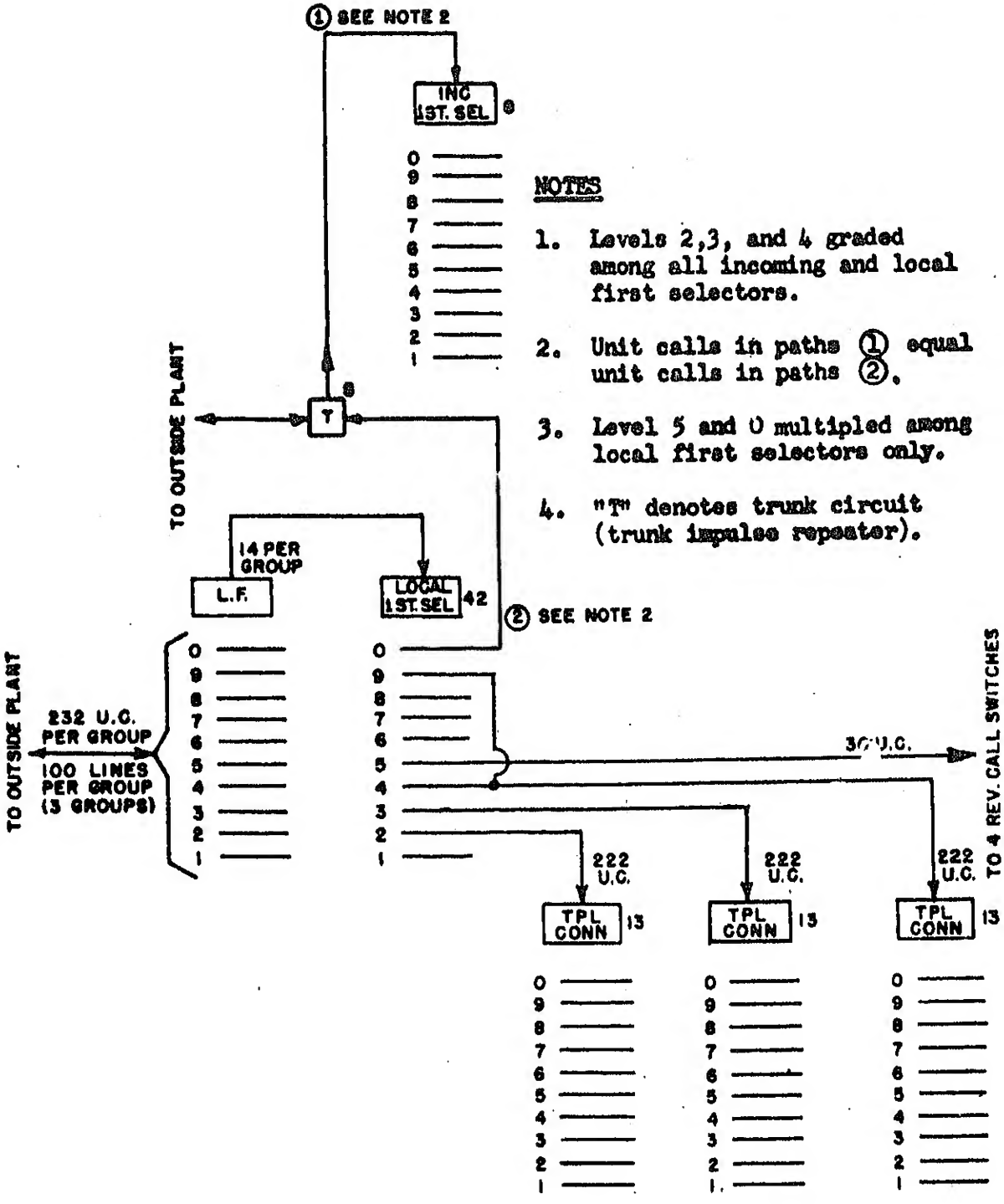
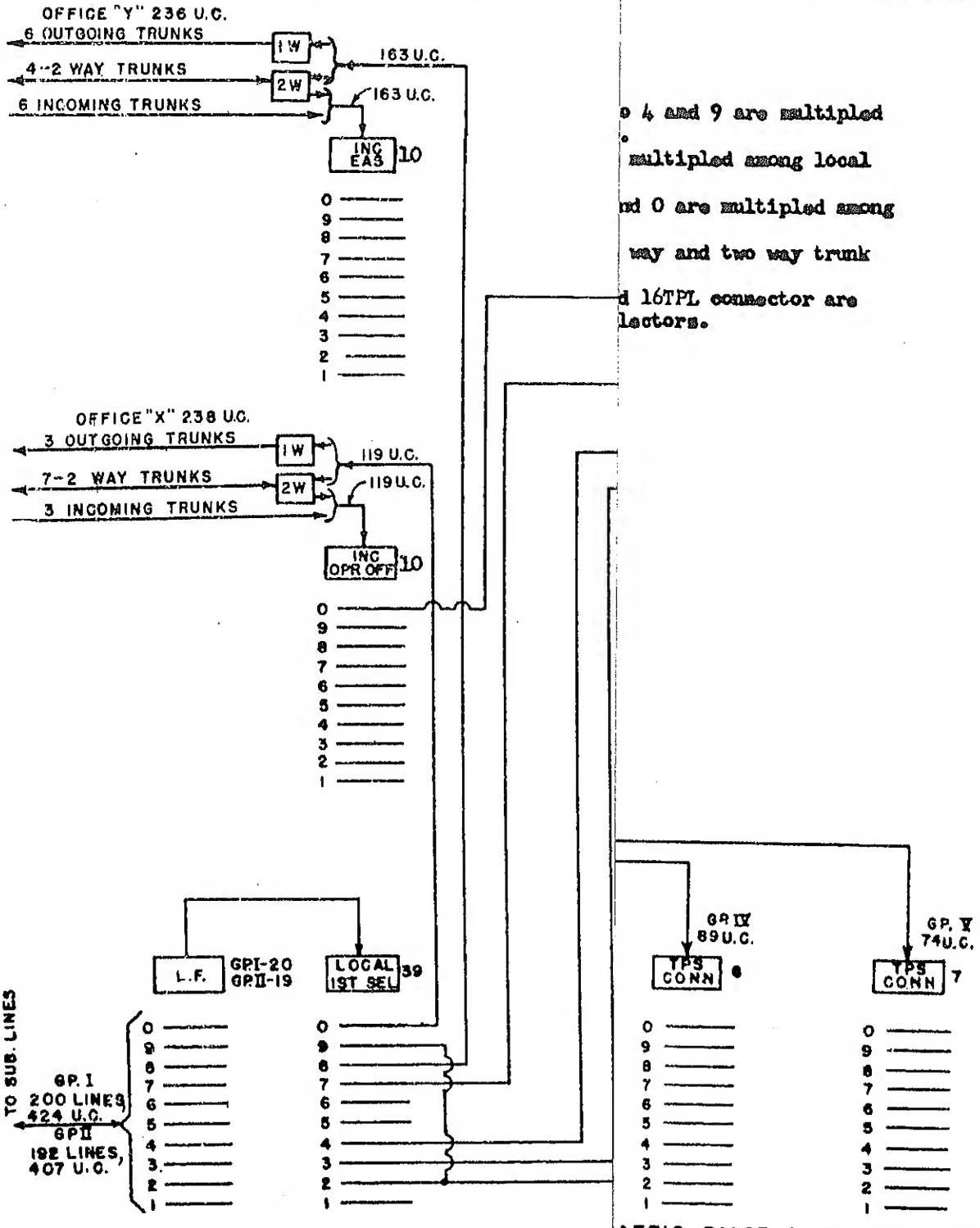


Figure 7
TRAFFIC DIAGRAM-EXAMPLE 5



o 4 and 9 are multipled

multipled among local

nd 0 are multipled among

way and two way trunk

d 16TPL connector are
lectors.

AFFIC DIAGRAM-EXAMPLE 6
Figure 8